

Animal Agriculture and Antibiotic Resistant Disease

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Abstract

What social, economic, or political factors affect the way antibiotic use is regulated in the US and subsequently, affect populations of microorganisms and humans? In the United States, farmers feed their animals antibiotics at low doses to prevent disease and promote their growth. Because the low doses do not kill all the bacteria, the bacteria that do survive will reproduce, and the strain eventually becomes resistant. Byproducts of animal farming, such as manure or runoff from farms, can carry with it antibiotic resistant diseases that can change the microbial dynamics of an ecosystem. These antibiotic resistant diseases that emerge from farms pose a health problem to the people who work with these animals and the people who consume them, as well as to wild animals that live nearby. However, the interests of pharmaceutical companies and large monopolizing food corporations means that the practice of recklessly using antibiotics for non medical purposes has continued. In order to regulate antibiotic use, we must address a root issues of the financial incentives that encourage antibiotic use, monopolization of the agriculture industry which limits the financial agency of individual farmers, and ag-gag laws which restrict the amount of information that can be collected on farm practices.

Introduction

Historically, disease has always thrived in agricultural societies, but today we face a growing danger due to the misuse of antibiotics. Antibiotics are commonly used in the animal agriculture industry to speed up the growth of livestock. The low dosages fed to animals promote antibiotic resistance by culling non resistant pathogens and allowing the fitter pathogens to survive and reproduce. These resistant diseases are difficult to treat and have many ways of spreading to humans through direct contact, food consumption, or the environment. Although there is clear evidence of the negative impacts of antibiotic overuse, financial interests of pharmaceutical and agricultural companies make it difficult for the government to regulate its use.

The human activity of farming promotes environments in which infectious diseases can thrive

The history of farming, illness, and veterinary medicine have long been entwined. Humans have a long history of treating illnesses in the animals they raise for food, since highly infectious disease arose at the same time as the Agricultural Revolution. Edward Jenner discovered the use of vaccines by studying cowpox infections spread from cows to farm hands—he noticed that individuals who had previously had cowpox were more resistant to a similar disease, smallpox (Jenner 1798). Jared Diamond asserts that the type of highly infectious diseases we have today would not be possible if not for the practice of agriculture, “because they can sustain themselves only in large dense populations that did not exist [before the Agricultural Revolution].” The shift from hunting and gathering societies to agricultural societies increased the frequency of interactions between humans and animals. The practice of keeping large numbers of animals in proximity to human settlements instead of hunting animals in the wild increased the chances of

transmitting pathogens from one to another. Agricultural changes to the environment such as forest clearing and construction of irrigation systems may have also made it easier for disease vectors such as mosquitos to thrive and access humans (Brinkworth 2017).

Agriculture also created an environment in which infectious diseases could thrive by driving population increase. Food availability increased, and a more sedentary lifestyle which shortened the amount of time possible between human births resulted in population growth. (Livi-Bassi 2001). As a result, people in agricultural societies lived in higher density, urban environments and more easily transmitted diseases to one another. Eventually agriculture outcompeted hunting and gathering as a means of food production, even though agriculture caused more work, worse nutritional value, and disease (Diamond 2002). Perhaps it persisted because food surplus and storage allowed the development of classes of jobs unrelated to food gathering, such as craftsmen and bureaucrats; and complex social hierarchies may make it easier for groups of people to survive and expand (Diamond 2002). Population growth and social stratification could give societies the power to take control of land and resources, even though the life quality and chances of individuals' survival are worsened. Because agriculture is the core of our modern society and affects all our lives either through direct consumption of food or involvement in the production of food, sustainable agriculture must take into account the public health aspect as well as environmental, to minimize the risk of resistant superbugs to future generations.

Coevolution between humans and diseases in ecosystems

Human hosts have always been coevolving with diseases. Ecologists normally model disease populations similar to predator and prey relationships, with parasites as predators and hosts as prey. Diseases evolve in response to changes in human immunity, because diseases can

only survive if they become more efficient at infecting and spreading to more people. However, humans are also simultaneously adapting to survive disease. Individual humans who are exposed to a disease and survive will be able to fight off the same pathogen more effectively in the future because their immune system will recognize and attack it. In addition, populations as a whole become more resistant over time when those with beneficial traits survive, reproduce and pass on their alleles (Diamond 2002). Various studies of human immune system genes suggest that exposure to pathogens results in selection for certain traits in humans and leads to diversification of the human genome (Brinkworth 2017).

But as we adapt to diseases, they simultaneously adapt to us, coevolving similar to a never ending arms race. Humans have expanded the niche they can occupy with technological advances in medicine—vaccines and antimicrobials allow people without a strong innate immunity to survive alongside diseases. But it is not surprising that pathogens have also found ways to circumvent our newest defense of antibiotics. Alexander Fleming, the discoverer of penicillin, famously warned during his Nobel Prize acceptance speech of how quickly bacteria develops resistance to antibiotic drugs (Wu 2017). This knowledge of the perpetual state of change and adaptation of diseases in our environment is an important reminder that our technology does not give us total control over the environment. A crucial point of view we must adopt in order to develop more sustainable ways of living is to recognize that humans are equals to other species, and that our actions in altering these ecosystems will inevitably come back to affect us.

Biological evolution of antibiotic resistance

Resistance often develops when people do not take antibiotics for the required length of time that is prescribed by their doctor, or because it is a common practice in agriculture to feed

antibiotics to animals at subtherapeutic doses. Exposing bacteria to doses of antibiotics that are not strong enough to kill all of them will eventually lead to a resistant strain, as the bacteria with traits that allow them to survive reproduce and pass on their genes. The trait of resistance spreads quickly throughout populations of bacteria. Due to a process called conjugation, genes do not even have to be passed on through reproduction to offspring; genetic material is present on the surfaces of cells and can move between individual microbes when they touch one another. This means that antibiotic resistance can be spread “horizontally,” and even across different types of pathogens—such as from an *E. coli* cell to a salmonella cell (Spinski 2017).

Bacteria that have only been exposed to one type of antibiotic can also become resistant to antibiotics they have never been exposed to. Resistant *E. coli* has been known to show up in the manure of birds that are fed antibiotics in as few as two days, and to develop resistance to other anti-biotics which the birds had never been exposed to (Williams-Smith 1969). Most antibiotics fight bacteria in one of a few specific ways, such as by attacking either the cell wall, ribosomes, or DNA of the cell (Learn.Genetics.Utah). It’s possible that this is why “families” of antibiotics which function in the same way can all become ineffective when a bacteria develops a more resistant cell wall, or methods to destroy remove the antibiotic from itself (CDC “Emerging Drug Resistance”). Even more worrisome is the fact that pharmaceutical companies have been less inclined lately to invest in creating new antibiotics because resistance develops too fast for them to make a profit (Spinski 2017). This means there is possibly an impending danger of new, highly resistant diseases but fewer people working on cures. The CDC recommends preventative strategies to protect people from getting any infections in the first place, as well as developing new antibiotics.

Spread of resistant diseases through ecosystems and human settlements

An important way to combat antibiotic resistant diseases is to understand how they spread through our ecosystems, especially from animals on farms to our communities. From a study on livestock-related pathogens in Iowa streams, researchers conclude that “Further research is needed to: 1) better understand the persistence and survival of manure-related zoonotic pathogens in water and sediment...[and] ascertain manure management techniques that can reduce zoonotic pathogen load to the environment” (Givens 2016). About 75 percent of antibiotics fed to livestock pass through their digestive systems undigested, and can continue to create resistance in other bacteria it encounters in the environment. (Chee Sanford 2009)

Although many manure management practices involve injecting or tilling the manure in a way that aims to minimize the amount swept away by rainfall, runoff still ends up spreading many antibiotics and antibiotic-resistant pathogens through our water systems. Runoff is not only transported by streams but may settle in sediment and be released later when the sediment is disrupted by human activities (Givens 2016). One study in Alberta, Canada linked a higher prevalence of zoonotic pathogens in surface waters (that are used for drinking, irrigation, and recreation) to increased rates of gastrointestinal disease occurrences in nearby communities (Givens 2016).

Zoonotic diseases are diseases which can affect more than one species. For example, the hepatitis E virus (HEV) has been found to infect swine and other domestic animals, as well as nearby wild rodents, deer, boar, and humans. Another possible route of disease transmission is environmental or wild fauna which “can become reservoirs of resistance and a source of reintroduction of resistant bacteria into the food-animal and human reservoirs” (Wegener 2012). Less is known about the effects of antibiotic use in aquaculture and its impacts on marine biota.

This is surprising, considering that the impact of dissolved antibiotics and resistant pathogens from aquaculture could spread through water systems. One study finds that “fishmeal product could itself be a reservoir of these bits of DNA and could promote their distribution globally,” promoting antibiotic resistance where it is fed to fish (America Chemical Society 2017).

Fishmeal is a major commodity worldwide and an example of how antibiotic resistance may soon be spread globally.

Agricultural antibiotic use

The irresponsible use of antibiotics for non medical purposes in animal agriculture is a major cause of antibiotic resistance. Of the medically important antibiotics used in the US (meaning antibiotics that are used to treat infections), about 70 percent are consumed by livestock (Spinski 2017). The Industrial Revolution mindset, when applied to farm practices meant a change in how animal products were produced. Most independent farms were replaced by concentrated animal feeding operations (CAFOs) which had the goal of packing as many animals into a space as possible, and raising them as quickly as possible (Imhoff 2010). In this system, raising animals would be impossible without using large amounts of antibiotics, because diseases could easily spread in such high density living environments (Imhoff 2010). In the 1950s, scientists conducted experiments to see if vitamin B12 makes chickens fatter. It seemed to work, but then they discovered that the effect was actually due to trace amounts of an antibiotic called aureomycin. The disease preventing benefits of using subtherapeutic doses of antibiotics allowed farmers to pack more animals into a space, and neglect sanitation without facing major decreases in productivity due to illness (Wu 2017). This discovery saved feed costs and the time it took to raise animals and antibiotic use skyrocketed. The use of antibiotics and CAFOs allowed a small number of large farms to produce most of the farmed animals in America, and

replace traditional farms. Our industrial, market economy culture still values pursuit of profit, over the health of animals, workers and consumers. Large agriculture companies sometimes pay farmers based on competition—so that the farmers who raise the largest amount of chickens with same amount of feed get paid more. In this kind of system, there is a high financial incentive for farmers to produce as many animals as possible and speed up their growth using antibiotics. In this top-down power structure, individual farmers who are indebted to their employers for their livelihoods are given little choice to use antibiotics.

The cost of antibiotic resistant diseases to society

It is widely recognized by medical professionals that the incorrect use of antibiotics can lead to people suffering from infections that are very hard to treat. The Centers for Disease Control and Prevention estimate that the minimum number of illnesses in the US caused by antibiotic resistance is over 2 million, and the number of deaths is 23,000. People affected by antibiotic resistant infections may have longer recovery times, higher medical expenses, and possible death (CDC “About Antimicrobial Resistance”). Studies estimate that antibiotic resistance “adds \$20 billion in excess direct health care costs, with additional costs to society for lost productivity as high as \$35 billion a year” (CDC “Untreatable”).

Obstacles to decreasing unnecessary antibiotic use: Consumer attitudes

An obvious way to prevent the spread of antibiotic resistance is to stop using antibiotics for non medical purposes—however the interests of large agricultural or pharmaceutical companies make it difficult to actually make this happen. Perdue, a large chicken seller that does not use antibiotics except for medical purposes cites consumers’ concern, as well as the possibility of future federal regulation as their main incentives for phasing out antibiotic use for growth purposes (Spinski 2017). Education and convincing consumers not to buy antibiotic fed animal

products may decrease the demand for them and prompt some farmers to stop using antibiotics to speed up growth. Recent studies suggest that the benefits of using antibiotics to prevent disease are not as significant as they were in the 1950s when they were first used, because of improvements in farm technology and hygiene standards (Spinski 2017). Raising animals in lower densities and cleaner conditions would help animals grow healthily and reduce the need for antibiotics, and using alternatives for disease prevention such as vaccines and probiotics could reduce the dangers of antibiotic resistance. But education may not be the only answer to changing consumer habits—many people now understand that switching to a plant-based diet would be better for the environment and for their own health, yet continue to eat meat. In a poll by Roper Organization asking which are the best reasons for being a vegetarian, 44 percent of respondents agreed that a vegetarian diet is better for one’s health, 22 percent said that such a diet is more economical, and 12 percent said that it’s wrong to kill animals for food. However, in Pew Research Center’s poll asking whether people identified as strict or mostly vegan or vegetarian, only 3 percent identified as strictly vegan/vegetarian, and 6 percent identified as mostly vegan/vegetarian—a much smaller percentage of all those who agree that vegetarianism is a good idea. What makes a person to feel that something is important enough to change an integral part of their life such as eating habits may have to do more with morality than their level of knowledge and education on the subject. The reasons that people do or do not switch to a lifestyle for values of animal welfare, environmental, and social justice may require a better understanding of social science and psychology. If changing consumer behaviors is the goal, we need to not only give people information on where their food comes from, but to somehow get them to feel that this information is meaningful enough that they change their habits.

Government Actions regarding antibiotic use in agriculture

In 2011 the Federal Drug Administration issued a “Guidance for Industry” which contains nonbinding recommendations to “(1) Limit medically important antimicrobial drugs to uses in animals that are considered necessary for assuring animal health, and (2) Limit medically important antimicrobial drugs to uses in animals that include veterinary oversight or consultation” (U.S. Department of Health and Human Services). The Guidance for Industry resulted in a change in labeling for medically important antibiotics fed to livestock. Many veterinary pharmaceutical companies voluntarily complied so that their drugs are no longer labeled for production purposes such as growth promotion or feed efficiency. A new Veterinary Feed Directive also requires producers to obtain medically important antibiotics with a veterinarian’s prescription and changed the over-the-counter status of some antibiotics to require a prescription (“GFI 213 Takes Hold”).

Obstacles to regulation: lobbyists

However, some are concerned that the FDA doesn’t go far enough because drug sponsors can re-label drugs for “disease prevention” instead of “growth promotion” and still not change how people use the antibiotics. Farmers may feed antibiotics to animals who are not necessarily sick, but which they believe may be “at risk” of getting an infection which is not much different from how antibiotics have always been used as a growth booster. So et al. recommend decreasing economic incentives that encourage inappropriate antibiotic use such as by a tax or other financial punishment. For example in Denmark, therapeutic use of antibiotics decreased by almost 25 percent after legislation was passed to make veterinarian incomes independent of antibiotic sales, reducing veterinarians’ motivations to sell inappropriately high amounts of

antibiotics (So et al. 2015). A warning letter system was also applied, with financial penalties to swine farmers who used excessively high amounts of antibiotics (So et al. 2015).

Why is the US government so reluctant to make laws restricting antibiotic use? Lobbying efforts and campaign contributions of veterinary pharmaceutical companies prevent bills related to antibiotic use regulation from getting through Congress. The nonprofit Center for Responsive Politics reports that “The National Chicken Council spent \$640,000 in 2015 to lobby, in part, against antibiotic-related legislation” and that pharmaceutical or farm organizations spent over \$15,000 in campaign donations to more than half of the members of the Health subcommittee of the House Energy and Commerce Committee of Congress (Moyer 2016). Since sales to agricultural companies make up most of antibiotic sales, pharmaceutical companies have a strong incentive to keep non-medical use of antibiotics legal.

The federal government focuses on giving suggestions and supporting research but has not made laws restricting or regulating antibiotic use in livestock. Certain states such as California have passed laws to ban antibiotic use for non medical purposes, but at the federal level the only bills that Congress has seen pertain to authorizing investigations, documenting, or funding research related to antibiotic resistance (CDDEP). For example, the Food, Conservation, and Energy Act signed into law in 2008 provided grants for research on antibiotic resistance in water or farms, and judicious use (CDDEP).

Obstacles to regulation: Lack of information on farm practices due to ag-gag

It is reasonable that the FDA chooses to focus on gathering more information; a main defensive argument for the continued use of antibiotics coming from the farm industry is that few antibiotic resistant infections found in hospitals can be traced to farms. One reason that little evidence exists linking animal products to resistant infections in humans is that the infections

sometimes occur much later after a person has ingested bacteria (Moyer 2016). Another reason for the lack of data is that scientists, and the general public are usually denied access to farms. Many farmers work for larger companies such as Tyson Foods or Smithfield Foods and risk punishment of losing their contracts and sources of revenue if they allow people onto their farms (Moyer 2016). One 2008 Johns Hopkins study involved tailgating trucks that were transporting chickens and was conducted in this way because researchers were not permitted access to the farms; afterwards they found that antibiotic resistant bacteria present on the interior surfaces of their cars (Moyer 2016). The U.S. Government Accountability Office reports that in order to better understand antibiotic resistance in agriculture, the FDA, HHS, and USDA should collect more farm-specific data, assess the effectiveness of their data collection and regulatory programs, and conduct on-farm investigations during food borne illness outbreaks (Office, U.G. 2017).

Monopolization of the food industry

A root cause of these difficulties in addressing problems in antibiotic use on farms is the enormous amount of power that large agricultural companies have over their contract farmers. Because a small number of companies make up most of the market in animal products, not only do consumers have limited choices in what to buy, but farmers also have less say in setting the prices of their goods and must accept the prices that meatpackers impose on them (National Sustainable Agriculture Coalition). The enforcement of anti-trust laws may promote fair competition in markets and prevent agricultural corporations from completely controlling farmers. Perhaps if individual farmers were less dependent on their employers for their livelihoods, it would be easier to convince them to collaborate with scientists or choose non-antibiotic options of raising livestock.

Conclusion

In conclusion, more research is needed to determine precise relationships between the presence of antibiotic use on farms and incidences of human infections, as well as to understand how to prevent such infections. The monopolistic structure of the livestock industry in the US and economic incentives severely limit the power of consumers and individual contract farmers to make choices regarding antibiotic use, and the government's ability to collect data and regulate antibiotics. Addressing societal causes that promote antibiotic use on farms, such as corporate monopolization of the farm industry, or consumer demand may help lower non medical use of antibiotics in livestock and improve food safety.

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